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U.S.A. Water Supply

"You can't escape the responsibility of tomorrow by evading it today." ABRAHAM LINCOLN

Water, land and air are the necessary substrate of any civilization. The harmonious relationship between them and all living creatures becomes surprisingly complex and increasingly difficult to maintain as millions of people live closer and closer together. As this country's population continues to grow rapidly during the rest of the century, especially in large cities and their environs, preservation of the ecological balance between man and his environment will be one of the great challenges facing the Nation.

Good fresh water, that priceless substance which all people take for granted until the well runs dry, has been so abundantly available, except in certain areas of the arid West, that the United States has always been a water-wealthy nation. In some parts of the East, short dry periods from time to time have brought restrictions on water use, but these are all too quickly forgotten in years of abundant rainfall.

Today, few Americans are aware that the Nation's fresh-water supply might be in serious trouble by the end of the century unless immediate, large-scale measures are taken to conserve this irreplaceable resource, protect its purity and develop new supplies. The greatest threat of all is pollution, that ominous "side effect" of industrialization, which now destroys the quality of water in many congested urban areas. As cities grow, pollution will multiply alarmingly unless there is vigorous effort to control it.

One glance at the country's potential population growth during the next four decades is sufficient to indicate that the demand for water will skyrocket dramatically. According to the Census Bureau's population projections, there will be between 232 and 274 million

people in the United States by 1980; and between 295 and 420 million by 2000. About 70 percent of the total population increase is expected in large cities and their suburbs.

In 1960, the United States used 60 percent of its water supply, compared with only 8 percent in 1900. It has been estimated that by 1975, just 14 years hence, the country will be using 88 percent of its total supply. Underground water supplies all across the country could be fully developed and utilized by 2000.

The myth that there will be enough water for everyone—even enough to make inland deserts bloom, now that the Nation's first desalination plant is in production, with others to follow—that myth could be a dangerous opiate. The importance of desalination in supplementing coastal fresh-water supplies can hardly be exaggerated.

However, even if the present high production and distribution costs are drastically reduced, desalination cannot be a magic solution to the water problem. It will not replace the depletion in precious fresh surface and underground water supplies. Only rain and snow can do this. When withdrawal is greater than replacement—as it is in some areas of the Southwest—water supplies are mined just as minerals are mined. Then the Nation's "water tank" is in serious trouble.

On the average, over a trillion gallons of rain water fall on the United States each day, or about 30 inches a year. However, there are big seasonal and geographic differences: the Pacific Northwest gets most, about 100 inches a year; and much of the rest of the West gets least, 20 inches or less. *The New York Times* recently reported that "Los Angeles received only 4.85 inches of rain in the year ended June 30, the driest on record. The three-year total of 18.61 inches is only 40 percent of normal. Portions of southern California, Nevada, Utah and Arizona expect water shortages this summer."

Water is the key to the future of the entire West. In all that vast area, only the Pacific Northwest has adequate supplies to maintain population and economic growth. This means the other regions of the West must face important decisions soon. They cannot continue both to support irrigation agriculture—the greatest water-hog of all—and to encourage urban-industrial expansion. The chronic water shortage in many arid regions would be greatly relieved if these regions would cut back sharply on irrigation agriculture and encourage industrial development.

Industry, the second largest water user, depletes comparatively little because recycling, which permits the same water to be used over and over again, is quite generally practiced. However, industrial saturation of the West would threaten the *quality* of water supplies unless rigid controls were applied to check industrial pollution.

Truly revolutionary changes can be accomplished in the West, despite the conflicts they imply, if

public interest is given priority over vested and political interests. Reorientation of social values would involve changes in laws, and these will not come easily or quickly.

In some arid parts of the West, population growth in recent decades has acutely depleted freshwater supplies which were limited long before those areas became migrant meccas. Water supplies now are being mined in certain parts of the Southwest: California's Central and San Joaquin Valleys, south central Arizona, the high plains country of northwestern Texas (where water mining since 1935 has practically exhausted reserves), eastern New Mexico and a small area of eastern Arkansas are already near the point of no return.

Ground-water supplies are now very limited in parts of Kentucky, West Virginia, Illinois, Indiana, Ohio, Pennsylvania, Tennessee, Georgia, Missouri, Oklahoma, Arkansas and Kansas. And, where local supplies are plentiful, the water is very hard.

The Middle West is not without its water problems. Surprisingly, some of the vast urban-industrial complexes in the Great Lakes region could feel the pressure of increasing demand on supplies before 1970 unless water reserves are more extensively developed.

The Midwest's most acute, immediate problem— drought and its customary companion, the grasshopper—has ruined crops in the Great Plains "dust bowl" area and the eastern part of some Western States. The Plains stretch across 386 million acres from Canada to Texas. The "dust bowl" consists of some 14 million acres of sandy soil suitable only as grassland. Only grass can hold the soil against the 55- to 90-mile-an-hour wind which frequently whips across the Plains. However, for many years now the land has been ploughed, reploughed and planted mainly with wheat. Its loose-lying, parched, sandy topsoil is being carried away by the wind, so the stage is set for a tragic recurrence of the disaster of 1934-1935 which extracted a heavy toll in land, livestock, and the livelihood of many. Thus, with the ecological balance again disturbed, Nature strikes back at man who carelessly rapes the land in his unending quest for a higher reward.

Throughout the populous East today and in the congested urban-industrial areas of the Middle West and West, pollution has already seriously reduced the quality of municipal water supplies. When population was sparse, conventional filtering systems and chlorine did the job. Now, as cities are becoming more and more congested, one city draws its water supply chiefly from another city's wastes, thereby endangering the health of all who live in the area.

Raritan Bay is a dramatic illustration of how a once beautiful waterway becomes a health hazard. Traditionally, the Bay is a catch-basin of human and industrial wastes from the congested New York-New Jersey megalopolis. Last May, the States of New York and New Jersey prohibited clam-har-

vesting there when it was found that raw Raritan Bay clams had a connection with an increase in the incidence of hepatitis, the liver-damaging disease. The United States Public Health Service has called for cooperative federal, state and local action to clean up the odorous mess resulting from a century of culminating abuses.

As population, urbanization and industrialization increase, environmental pollutants of all kinds will also increase. Unless an aroused public insists that measures be taken to control them, these pollutants will continue to threaten the quality of the water people drink, the food they eat and the air they breathe.

Control is possible today. However, like the water-shortage problem of the West, the pollution problem has social, economic and political overtones, and these could delay the decisions which must be made within the next few decades. Pollution control will come when the public insists upon the necessary remedial action which is available and so sorely needed now. Left to mere happenstance, the future outlook for the Nation's water supply is far from reassuring. But if the people of the United States would exercise a modicum of ecological wisdom, there would be little need for alarm.

The "pure water bill," passed by Congress in July and just signed by President Kennedy as this issue goes to press, should help to check the dangerous apathy which has created the current crisis. This bill provides for a $570 million federal program which will greatly expand and strengthen the control of water pollution throughout the country. Matching grants will be made to states, counties and localities for the construction of water-treatment and sewage-disposal facilities. Every $3.00 in federal funds will require $7.00 in community funds. One half of the total amount will go to communities with populations of 125,000 or less.

The measure gives the Government the power to take action against communities or industries that pollute the water from which supplies are drawn. It also provides for an expanded research program designed to protect the purity of those water supplies.

To focus attention on this vital resource which deserves continuing evaluation, this issue presents a survey of the Nation's fresh-water supply which was prepared by Dr. Robert Z. Brown, Director, Water-Use Education Center of the Conservation Foundation at the Colorado College, Colorado Springs, Colorado. Dr. Brown has devoted many years to the study of ecological problems. His sobering report should be read by all who hope that their children and grandchildren may also enjoy that priceless gift—good fresh water—which too many Americans have too long taken for granted.

—ROBERT C. COOK, *Editor*

UNITED STATES WATER SUPPLY
vs.
POPULATION GROWTH

by Robert Z. Brown

There are three principal components of the developing water problem in the United States. First, there is a finite quantity of fresh water available, and there are no developments in sight which will substantially increase this amount. Second, the population of this country is growing quite rapidly, especially in water-scarce areas. This of and by itself raises water requirements. Third, there has been a steady increase in the per capita consumption of water during the past several decades and undoubtedly this trend will continue.

The interaction of these three components is unbelievably complex. The tremendous variety of uses to which water is put and its crucial importance as a basic element in life, agriculture and industry enormously complicate the problem of its allocation. Compared with many other countries of the world, the United States is generally water-rich. This is why water problems have received very little attention except in a few local areas, usually in times of serious drought. Suddenly, the impact of a rapidly increasing population whose level of living has been continually rising begins to affect the Nation's water supply. What does this portend for the future?

Until there is a decline in the Nation's birth rate, rapid population growth will continue. Should the Census Bureau's medium population estimates be realized, today's 180 million people will grow to 261 in 1980 and to 383 million in 2000. Quite clearly, the steady increase in population will mean an accelerating demand on the Nation's water supply.

In the immediately foreseeable future, some areas of the United States will have no more water supplies to develop. The supplies of other areas will be so badly polluted that they will be totally unfit for many uses. By 1980—certainly by the year 2000—most of the water supplies of the United States will have been developed to their practicable limits.[10*]

THE PROBLEM OF SUPPLY

The total amount of fresh water available in the United States (excluding Hawaii and Alaska) averages just under 1,100 billion gallons daily.[10] There is some reason to believe that this quantity is sufficient for the Nation's healthy economic growth through the year 2000. By that time, the available supply and the demand might be perilously close. It will undoubtedly be extremely costly to develop further the few remaining supplies.

However, this hypothetical demand-supply ratio assumes that a

*Numbers refer to sources listed at the end of this report.

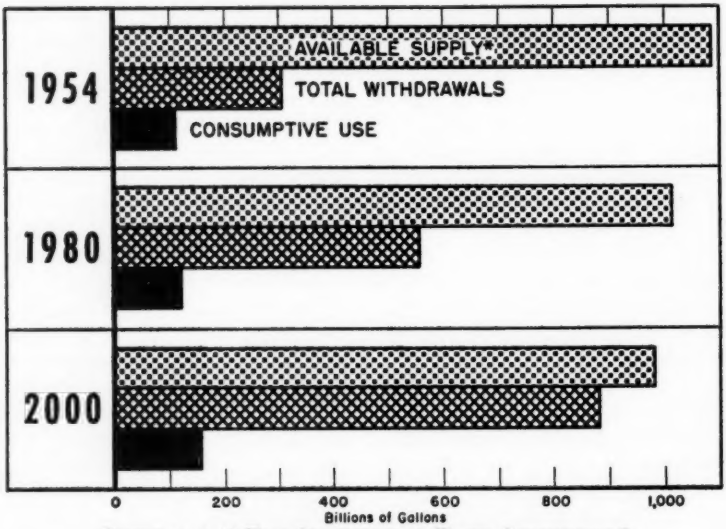


FIGURE 1: A 40-YEAR PROJECTION OF WATER CONSUMPTION*

"Available supply" is assumed to be the average stream flow that can be sustained under 1954 conditions. The decline in available supply will be due to an increase in wetlands and watershed improvement programs which retain water on site. "Consumptive use" means that water is not returned to the available supply after use.

relatively comprehensive, efficient water development program will be carried out during the next 40 years. In the past, water problems have been given priority only when emergencies developed. Long-range plans have neither been adequate nor activated until situations have reached a crisis stage. The probabilities are good that this costly approach will continue, now that many have been led to believe that desalination has solved all of the Nation's water problems.

It is true that excellent long-range plans have been formulated, but they face a hard fight for implementation. Some of these plans are so vast that their success requires the cooperative effort of very large numbers of individuals, agencies and political units. The large amount of current litigation over water rights suggests that the problem of cooperation may well be one of the most serious which the Nation must face.

In addition, the nationwide estimates of water supply conceal the obvious fact that this supply shows great variability both in space and time. As will be seen, there are areas which are using their reserves faster than these are being replenished while others have great quantities as yet undeveloped.

*Figures 1, 4, 5 and 6 are based on data from the U. S. Senate, Select Committee on National Water Resources.[10]

RAINFALL REPLENISHES WATER SUPPLIES

All of the fresh-water supplies of the United States arrive in the form of rainfall. The average annual fall for the country is about 30 inches, but the amount varies greatly from one area to the next, and from year to year. In the Pacific Northwest, over 100 inches fall annually on the mountains swept by Pacific, moisture-laden air. Throughout most of the rest of the West, precipitation averages 20 inches or less per year, with Death Valley, California, recording less than two inches. The western mountain masses are generally "islands of moisture" which intercept air masses moving from west to east. The intervening valleys and basins receive their water primarily from runoff from these mountains. East of the 100th meridian, roughly the geographic center of the country, rainfall is more uniformly distributed, and more plentiful, ranging generally from about 30 to 50 inches per year. In the southern Appalachian Mountains, the average annual rainfall may be as high as 80 inches.

Two thirds of the rain that falls is returned to the atmosphere by evapotranspiration. This is the evaporation from the surface of bodies of water, from the soil and from loss by transpiration from plants. The difference between evapotranspiration and rainfall amounts to runoff. Thus, any measure of the relationship of precipitation to losses from evapotranspiration will indicate the relative wetness of an area. Figure 2 shows this relationship for the contiguous states in terms of the potential rather than the actual evapotranspiration. This is the water loss that would occur if a continuous supply of water were available. The map indicates the chief patterns of water availability in this country: little or no deficiency; seasonal deficiency of varying severity in summer; and little or no water surplus at any season.

The runoff remaining consti-

TABLE I. AVERAGE REMAINING RUNOFF FOR REGIONS IN THE UNITED STATES

Region	Total Long-time Average Remaining Runoff (Billion gal/day)	Area (Thousand Sq. Miles)	Average Runoff Daily per Sq. Mile (Thousand Gal.)
Eastern[1]	403.0	473	852
Central[2]	212.0	285	744
Middle Western[3]	287.0	1,301	221
Southwestern[4]	54.0	706	77
Northwestern	143.0	257	556

[1]All streams flowing into Atlantic and Gulf except Mississippi and Rio Grande. Includes Lakes Ontario and Erie.
[2]Remaining Great Lakes, Ohio, Cumberland, and Tennessee Rivers.
[3]Mississippi-Missouri system.
[4]All streams flowing into Pacific except in Northwest. Also includes Rio Grande.

Based on data from Committee Print 3. Select Committee on National Warter Resources, U. S. Senate 1960.

tutes the supply available to man. The distribution, of course, varies according to the wetness of the area. Table I shows the average long-time runoff for the major areas of the United States, but these data do not tell the local story. Within the Southwest region, the local supply for southern California is completely depleted; total water appropriations already exceed the supply on the upper Rio Grande-Pecos River system. Within a decade or two, the Colorado River system, the Great Basin country of Nevada and Utah and the entire upper Missouri River system will be fully utilized. Within four decades the same will be true for the upper Arkansas River, the Red River of Oklahoma, Texas and Louisiana and possibly the western Great Lakes region.[10]

Currently, some of the Nation's water-short areas face serious drought. The severity of the current runoff situation in the West is revealed by the April 1, 1961 snow runoff forecast compiled by the United States Department of Agriculture. This points out that for the third year in succession there will be an extreme shortage of runoff in Utah and Nevada, in southwestern Oregon and in the Central Valley of California. The total flow in California streams during the period of 1959-61 is expected to be near the minimum for any three-year period in this century. Across the rest of the West, runoff will be slightly below average. Only in the Pacific Northwest, much of Colorado and eastern New Mexico will runoff be near normal.[10F]

GROUND-WATER SUPPLIES VARY GREATLY

In addition to runoff, a vast amount of water exists underground in the United States. About 20 percent of the water used today is ground water.[10D] The amount available varies greatly in different regions. In the Atlantic and Gulf Coastal Plain areas, there are abundant supplies in the sands and limestones but along the coasts encroaching salt water has destroyed some of the water quality.

Large water reserves that are only partly known exist in Virgina, the Carolinas, Georgia, Mississippi and, until recently, Alabama. However, these states have been laggard in their surveys of water resources. Florida and Texas have been more active in this respect.

While ground water supplies are more limited in the Appalachian Mountains and the Piedmont plateau, very reliable small supplies exist there. In the glaciated regions of New England and the Great Lakes states, there appears to be a substantial amount of ground water.

In the central unglaciated states of Kentucky and West Virginia and in parts of Illinois, Indiana, Ohio, Pennsylvania and Tennessee, the ground-water potential is very limited. Where local supplies are abundant, the water is very hard. The same is true for much of Missouri, Oklahoma, Arkansas and eastern Kansas. In the southern Great Plains, abundant supplies

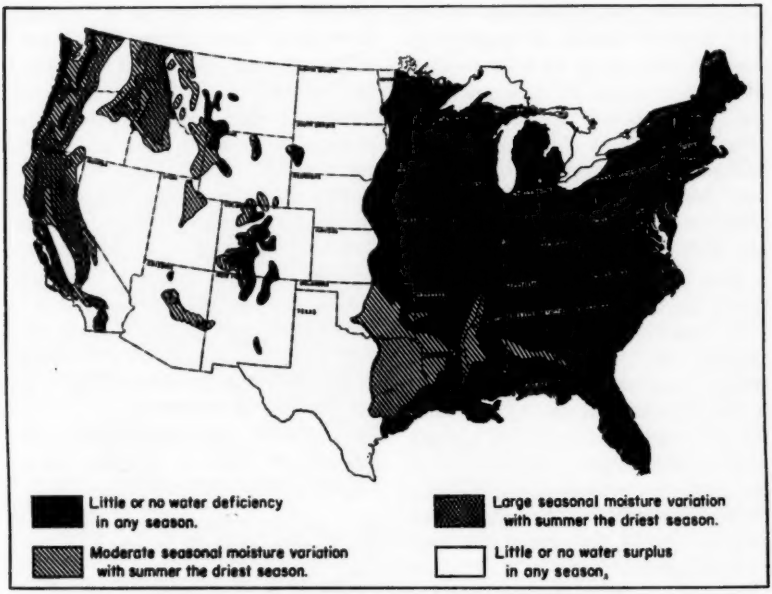

Little or no water deficiency in any season.
Large seasonal moisture variation with summer the driest season.
Moderate seasonal moisture variation with summer the driest season.
Little or no water surplus in any season.

FIGURE 2: SEASONAL VARIATION IN EFFECTIVE MOISTURE
This map shows the patterns of water availability throughout the United States. The water loss a region suffers through the evaporation of moisture from surface water and soil and by transpiration of plants determines its effective moisture. Though the moist areas have an ample average supply, large seasonal variations in summer rainfall can cause serious local shortages. The Western regions with dry summers depend on winter precipitation for the reserves. (Modified from map by American Geographical Society of New York.)

exist but replenishment is very poor. Here water, like petroleum, is essentially a non-renewable resource. Supplies are generally poor in the Rocky Mountain region. In the basin and range country of the Southwest and West, supplies are good but recharge is inadequate. In contrast, the Columbia plateau country of Oregon, Washington and Idaho is rich in ground water; and the Snake River plain has one of the largest underdeveloped ground-water supplies in the country.[10D]

DESALINATION AND WEATHER CONTROL

Converting salt water from the ocean has received a considerable amount of attention in recent years, and the Department of Interior's Office of Saline Water has conducted extensive research. The first of its five desalination demonstration plants was dedicated in Freeport, Texas, in June. This plant purifies a million gallons of water a day at a cost of $1.00 to $1.25 per 1,000 gallons, the lowest conversion cost achieved thus far.

It has been estimated that within five years it should be possible to convert salt water on a large scale at a cost of about 30 cents per 1,000 gallons.[88] Since this will require large amounts of cheap power, desalination may prove to be feasible only for large cities and industries. Distribution will be a major problem in the future.

The dream of making the Nation's inland deserts bloom could be a prohibitively expensive undertaking. The tremendous volume of water required for irrigation would make agricultural use of the land far too expensive, even for highest dollar-yield crops. The cost of pumping the processed water away from the coast to large irrigation projects would far exceed the cost of desalination.

A very rough approximation indicates that it would cost $27.00 per acre-foot (an acre-foot equals almost 326,000 gallons) to pump 100 miles with a 500-foot lift, assuming that equipment and pipeline were amortized over a 20-year period. At $1.00 per 1,000 gallons, the desalination of an acre-foot of water would cost $326.00. Adding the estimated pumping costs for 100 miles only would bring the total cost to $353 per acre-foot. The highest cost which Colorado farmers estimate they can afford for irrigation water is $5.30 per acre-foot. For areas far removed from the sea, it might be more feasible to process local brackish water or exchange water rights.

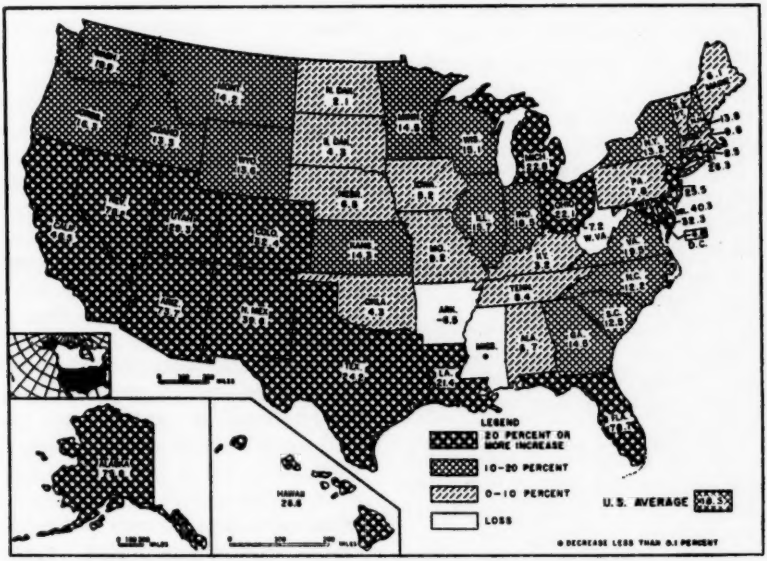
Much has been said recently about the promise of artificial weather control, but so far results have been inconclusive. The possibility of some local control exists, but widespread rearrangement of weather patterns sufficient to change large river systems is not yet a serious possibility.

The most promising factor in a thoroughly discouraging outlook for the Nation's available water supply is that current research may add up to 325 billion gallons a year to supplies in the West in the next decade. This includes research in water-saving techniques, such as destruction of water-using streambank plants (phreatophytes), reduction of reservoir evaporation and improved irrigation methods.

POPULATION GROWTH AND WATER SUPPLY

The rate of population growth of a given area is the major factor determining water-use projections for that area. Since the close of World War II, the population of the United States has increased steadily as a result of an extremely high rate of natural increase (births minus deaths) for an industrial country. During the past decade, population grew from over 150 million to nearly 180 million, an increase of over 18 percent. The rate of natural increase varied in different areas. It ranged between 14 and 21 percent in 42 states and the District of Columbia. It was relatively high in the Deep South and in the Mountain States and low throughout the Northeast.

Census Bureau projections indicate that by 1970 the population will be between 204 and 221 mil-



(U.S. Bureau of the Census)

FIGURE 3: THE WESTWARD SHIFT OF THE U.S. POPULATION

This map shows the percent change in population by states between 1950 and 1960. Seven out of 15 mainland states which registered the greatest gain in population were in the arid West and Southwest.

lion. Should the middle estimate materialize, there will be about 214 million people, an increase of over 16 percent during this decade. Projections for 1980 range from a low of 232 million, a middle estimate of 261 million and a high of 274 million. It might be noted, parenthetically, that the present population increase is tending toward the higher estimates. Very obviously, population growth will place heavy demands on the Nation's water resources even during the next generation.

Resources for the Future, Inc., a nonprofit, research organization, has projected population to the year 2000 on assumptions consistent with the Census Reports. These projections show that the range lies between 267 and 431 million—a large margin of error! The medium high projection gives a total of 380 million. This essentially carries forward the present rate of growth which will double the population in about 40 years.

MIGRATION FURTHER COMPLICATES SUPPLY PROBLEM

In planning for the future water needs of the Nation, the total increase in population tells only part of the story. Where the people live is more important than where they were born. Thus, the fact that our

people are highly mobile is of prime importance. During the 1950's, two long-term migratory trends continued: to the west and to the city. Both of these trends complicated the water situation. The trek to the west moved millions of people into areas which already were actually short of water. Table II shows the projected distribution prepared for the Kerr Committee on a basis of medium assumptions regarding growth and migration. This reveals a relatively high rate of increase for the Western States, which may be checked by the water shortage.

Of the 15 mainland states showing the greatest gain in population between 1950 and 1960, seven were in the West and Southwest:

State	Increase, 1950 to 1960 Population	Percent
Nevada	125,195	78.2
Arizona	552,574	73.7
California	5,130,981	48.5
New Mexico	269,836	39.6
Colorado	428,858	32.4
Utah	201,765	29.3
Texas	1,868,483	24.2
Total	8,577,692	

The increment of nearly nine million people in ten years in states which are already facing an acute water famine is a social and political phenomenon of the greatest importance. The matter is further complicated by the fact that most of the increase occurred in cities where water supplies were already in serious trouble.

Even in the water-rich East, the large accretions of population in the metropolitan centers have already put a heavy strain on many municipal water supplies. The greatest increases in population are expected in the Delaware and Hudson River Valleys, in the Southeast, along the Ohio River, around the Great Lakes and along the Mississippi River above St. Louis.

What does the future hold with respect to population growth in

TABLE II. NUMBERS AND PERCENT DISTRIBUTION OF POPULATION BY MAJOR REGIONS OF THE UNITED STATES 1960-2000

Region	1960		1980		2000	
	Number	Percent	Number (thousands)	Percent	Number (thousands)	Percent
New England	10,509,367	6	13,878	5	19,809	5
Middle Atlantic	34,168,452	19	45,943	18	65,475	17
East North Central	36,225,024	20	53,959	21	79,635	21
West North Central	15,394,115	9	21,219	8	30,133	8
South Atlantic	25,971,732	14	39,353	15	58,606	15
East South Central	12,050,126	7	16,553	6	23,541	6
West South Central	16,951,255	9	24,787	10	36,424	10
Mountain	6,855,060	4	10,865	4	16,685	4
Pacific	21,198,044	12	34,023	13	52,763	14
Total	179,353,175		260,578		383,072	

Source: Col. 2: U. S. Bureau of the Census, 1960 Census of Population, Series PC (A1)-1 Nov., 1960; Cols. 3 & 4: U. S. Senate Select Committee on National Water Resources, Committee Print 5, ("Population Projections and Economic Assumptions," Committee Staff U. S. Census Bureau and Resources for the Future staff, 1960, P. 28.

the water-poor areas? Desalination will help to relieve the problem in coastal regions, but that the entire Southwest will be piped for desalted ocean water seems improbable. That inland communities will continue to flourish when their wells or streams run dry is quite impossible.

It is likely that since water is finite, it could be a determinant limiting population growth. Present high growth rates can hardly continue indefinitely. Census Bureau population projections for the East and West indicate that almost 30 percent of the country's population may be living in the arid West by the year 2000. Water, rather the lack of it, could decisively check that trend unless the West cuts back sharply on irrigation agriculture and encourages industrial development. It cannot have both. Economic and population growth projections which ignore the effect of the water-balance in this area are not likely to prove very accurate.

Large-scale relief might come to certain inland areas if the problem of water distribution could be objectively re-examined. To illustrate, if a coastal city like Los Angeles were to rely heavily on desalination, and release its downstream water rights in favor of the upstream water rights on the many river systems now serving the city, more water would be available to some inland areas. Such redistribution of water would involve the closest cooperation of all interests involved. Heretofore, questions of distribution have created intense conflict and prolonged litigation.

WHERE THE WATER GOES

Current water-use patterns are in a rapid state of flux. Of all the water now in use, it is estimated that industry and agriculture each use about 46 percent and that 8 percent goes for municipal supplies.

The demand for water across the country varies with the density of the population, the type of use and the season. The drain on municipal supplies is relatively constant throughout the year. The demand for irrigation water, on the other hand, is concentrated in the growing season which is approximately four months a year in all regions except in the deep Southwest where it is six months. The demand for industrial water varies: it is constant for some industries and seasonal for others, such as refrigeration and air-conditioning.

Senator Robert S. Kerr, Chairman of the Senate Select Committee on National Water Resources, reports that in 1960 farming used 760 gallons of water per capita each day and industry used 849 gallons. This compared with 644 and 560 gallons, respectively, in 1950. Kerr estimates that by 1975 farming will have stabilized at 821 gallons daily per capita and that industry will be up to a whopping 1,193 gallons.[2]

When considering projections of water use it is important to recognize that water has two possible fates as far as man is concerned: it is depleted or it is returned for re-use. Generally speaking, water is depleted in quantity through evap-

oration and transpiration to the atmosphere; hence, it is not recoverable. Irrigation depletes 60 percent or more of the water used, but no more than 12 percent of the water is depleted in municipal use.

On the other hand, industry withdraws great quantities of water but depletes only about 9 percent, on the average. Over 85 percent of all industrial water is used for cooling and then discharged back into the streams. The significant change is in quality, not in quantity. This introduces the very serious problem of pollution which will be discussed more fully later.

Mining operations deplete about 20 percent of the water withdrawn. Steam electric-power-cooling uses vast quantities of water (74.1 billion gallons per day in 1954) and depletes only about 0.5 percent of the withdrawals.[10D] Table III shows the withdrawals and depletions for major users for 1954, and estimates for 1980 and 2000.

The patterns and attendant problems of water use differ in the East and in the West. In most of the heavily populated, industrialized East, water supplies are relatively abundant (some notable exceptions are mentioned later), and the problem of supply depletion is minor. The problem, *quality*, is very serious because of heavy use and re-use. In the more sparsely populated West, most of the water used is for irrigation. Since this causes a very heavy consumptive loss, it contributes to the ever-more serious supply problem in the arid lands. Over much of the West, particularly in the Southwest, the demand is often much greater than the supply.

BITTER CONTROVERSIES ARISE OVER WATER USE

Water problems are further complicated by the fact that the supply and the demand often do not coincide geographically. For example, the city of Los Angeles lies in water-starved southern California where local supplies of about 1,100 cubic feet per second are exhausted.[10] Southern California now imports water from the Owens River, the Mono River and the Colorado River. The aqueduct stretching 250 miles across the desert to the Colorado River is now carrying to Los Angeles and its environs over 550 cubic feet per second and could carry 1,600 feet. However, the water rights for the aqueduct are currently in litigation before the United States Supreme Court.

California is planning a giant diversion program to bring water 400 miles to Los Angeles through an aqueduct from the Feather River in the northern part of the state. The completion deadline is 1970, when the capacity of the Colorado River aqueduct will have been reached. The estimated cost of the giant Feather River storage dam is $457 million; of the 400-mile aqueduct, $1.3 billion. The ultimate cost of the entire project —dam, aqueducts and tunnels— may be as high as $10 billion. This gigantic diversion project has produced considerable sectional controversy in the state, and not only because of its staggering cost. Wa-

ter-rich northern Californians oppose any program which might stifle their own economic development and they resent the persistent and often desperate inroads made on the water supply by the booming, water-short communities to the south.

Such inter-basin transfers of water have produced some of the West's most bitter controversies. The most prolonged has resulted in litigation now before the United States Supreme Court with Arizona challenging the Congressional apportionment of Colorado River water which dates back to 1921. Then Congress authorized the negotiation of the Colorado River Compact, an agreement among the seven states in the Colorado River Basin which was to solve the problem of reasonable and equitable water apportionment. The Compact was never ratified by Arizona; and the reason given was its failure to recognize adequately the irrigation systems on the Gila River. Congress has subsequently undertaken to carry out the apportionment of the water, part of which must go to Mexico by treaty. Through its actions, Congress has limited the water appropriated by California. Arizona, however, has challenged this Congressional appropriation.

Another controversy has raged over inter-basin diversion from the western slope of Colorado to the dry and populous eastern slope (Denver, Colorado Springs, Pueblo). Even though these diversions represent the only hope for adequate supplies for these cities, considerable hard feelings have been aroused.

TABLE III. TOTAL REQUIREMENTS FOR WITHDRAWALS AND CONSUMPTIVE USES OR DEPLETIONS FROM STREAMFLOW

	Gross Withdrawals (billion gallons per day)			Net Consumptive uses or depletions from Streamflow		
	1954	1980	2000	1954	1980	2000
Diversions:						
Irrigation	176.1	167	184.5	103.9	104.5	126.3
Municipal	16.7	28.5	42.2	2.1	3.7	5.5
Manufacturing	31.9	101.6	229.2	2.8	8.7	20.8
Mining	1.5	2.7	3.4	.3	.6	.7
Steam electric power-cooling	74.1	258.9	429.4	.4	1.7	2.9
Subtotal, Withdrawals and Consumptive uses	300.3	558.9	888.4	109.5	119.3	156.3
Onsite Uses:						
Watershed improvement programs					4.0	
Swamps and wetlands for wildlife					66.7	
Subtotal onsite depletions					70.7	
Total of consumptive uses and depletions					190.0	253.2

Source: Report of the Select Committee on National Water Resources, U. S. Senate.

Such controversies can only be multiplied and intensified as the growing population places increasing demand on water supplies in many parts of the West. New Mexico is a case in point. All of the water in the Rio Grande-Pecos River system has been appropriated as of now.[3] Essentially, this means no further development of new water sources in most of the state unless new water can be added. In northwestern New Mexico, the San Juan River carries 2.2 million acre-feet per year out of the state. The Colorado River Compact authorizes New Mexico to deplete the flow by about 840,000 acre-feet per year. Currently, only 92,000 acre-feet are being depleted. With the San Juan-Chama project, New Mexico expects to divert up to 235,000 acre-feet a year to the Rio Grande Basin. It is estimated that initial stages of this project will meet the needs of Albuquerque well beyond 1980, assuming that city continues to grow at its present rate. The San Juan River system represents the last major undeveloped water source in the state. When this water is completely appropriated, New Mexico will have no other reserves to develop.

GROUND-WATER RESERVES ALREADY BEING MINED IN SOME AREAS

The ground-water reserves lying beneath the earth's surface are being subjected to ever-increasing exploitation as water demands multiply. These reserves are very large although irregularly distributed. They depend on rainfall and runoff for replenishment. Recharge is adequate in the East but very poor in the West where the demand on ground water is heaviest.

When the pumping rate of ground water is greater than the annual recharge, reserves are "mined" and depletion results. Water mining is occurring now in several areas of the West, notably in the Central and the San Joaquin Valleys of California, south central Arizona, the high plains of northwestern Texas and eastern New Mexico and a small area of eastern Arkansas.[3] Water mining has been a common practice in the high plains of Texas since 1935 when pumping removed water equal to the annual recharge rate of 50,000 acre-feet.[10D] By 1958, annual withdrawal had reached seven million acre-feet. If continued, this rate of pumping will exhaust this gigantic reserve of 200 million acre-feet in about 30 years.

In New Mexico, extensive water mining is rapidly depleting ground water. As pumping continues, water levels drop and the cost of pumping increases. In several of the closed basins of the state, the thickness of the ground-water layer is so great (up to several thousand feet) that the cost of pumping eventually will prohibit water mining.

Moreover, as ground water is pumped from the Pecos River Valley, saline water seeps into the reserves. As a result, the area around Roswell, New Mexico, already faces a serious change in water quality.[10H] In the San Joaquin Valley of California, over six billion gallons of

water per day are being withdrawn from some 40,000 wells.[8] This represents a daily overdraft in excess of one billion gallons. Formerly, water was obtainable at the eight-foot level in Santa Clara. California. Now drillers must go below 200 feet to reach the ground water.[10G]

Depletion pumping sometimes reduces surface supplies in nearby streams. The flow of the Rio Grande River has been so seriously curtailed by this practice that New Mexico's State Engineer has ruled that additional wells may not be drilled unless surface water rights are acquired.[10D] Stream flow has also been seriously reduced in parts of Nebraska, Kansas, Colorado, California and Arizona.

Those who mine ground water use their water as a renewable natural resource when, in fact, it is non-renewable. Where the removal rate is high and the recharge rate very low, the water situation is similar to that of petroleum and other minerals. When the supply is gone, operations cease. Irrigation agriculture is the primary user in water mining areas. As the water becomes exhausted during the next few decades, agriculture and the economy it suports will begin to disappear rapidly. The only agriculture remaining in large areas of the Southwest and the southern plains will rely on surface flow.

IRRIGATION DEMANDS

The extent of irrigation farming varies greatly throughout the United States. The greatest amount of irrigation water is used in the West and the western Gulf regions, and demands will increase as long as supplies hold out. The practice of irrigation is expected to increase in all other areas, even in the relatively humid East, for several reasons. In a dry summer, normal in the West, irrigated land produces, on the average, three times the yield as non-irrigated land; thus it generally has a very high yield; because it need not lie fallow in dry summer months, it is rarely idle; and irrigated land leads to an increase in crop diversity and permits production of high-income crops. More and more emphasis is given to the production of livestock, as well as fruits and vegetables, on irrigated lands because this reduces losses from dry spells.

Many changes may be expected in irrigated acreage by 1980 and 2000. Assuming no increase in the efficiency of application and transmission of irrigation water, it is estimated that an additional 56 million acre-feet of water would be needed to meet the irrigation requirements by 2000.[10A]

However, it is reasonable to expect greater efficiency. Currently, irrigation ditches are extensively being lined to prevent loss through seepage, and this practice undoubtedly will accelerate as water in the West becomes more completely appropriated. Consequently, the estimates shown in Table IV for total water needed for irrigation in the next four decades show no substantial increase.

It should be emphasized that greater efficiency in irrigation practice does not mean that there

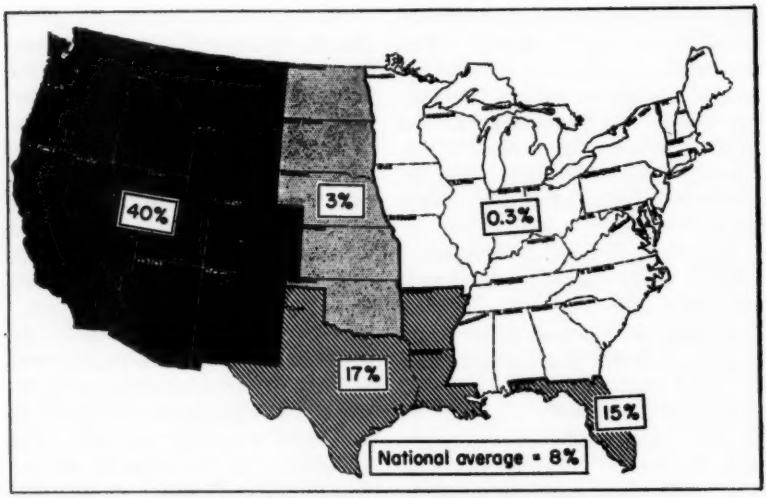


FIGURE 4: PERCENTAGE CROP LAND UNDER IRRIGATION

Irrigation agriculture predominates in the West and Southwest. There is a large potential agricultural acreage in the West, but water shortages threaten irrigation in some areas dependent on "mined" water and in other areas of mushrooming urban and industrial development.

will be little need to develop more water supplies for irrigation. As previously stated, much of the irrigated land in the water-mining regions of the West will have to be withdrawn from agricultural production in the next few decades. Furthermore, as urban centers continue their relentless expansion in other areas, much of the Nation's prime crop land will continue to be swallowed up by municipal and industrial encroachment. It is expected that between now and the end of the century, approximately 75 percent of the country's population growth will be in cities. Obviously, today's urban sprawl is merely a sample of what is to come.

A case in point is Phoenix, Arizona, where the water supply comes from the Salt River which is already fully developed. Water from this river formerly supplied an extensive area of irrigated land. Phoenix is one of the Nation's most rapidly growing cities with a population increase of 311 percent between 1950 and 1960![8A] The city is expanding rapidly across the surrounding irrigated land (by Arizona law, the water and the land remain together). In the not-too-distant future, almost all of the irrigated land of this rich agricultural area will have been engulfed by urbanization.

Across the Nation, soil erosion, tree culture and water-logging also take irrigated land out of production. The net result is that the total

crop land of the United States—about 35 million acres—has not increased substantially in the last 40 years. Increased agricultural production has been due primarily to increased efficiency resulting from more mechanization and irrigation and to improved livestock, seeds and fertilizers. Spectacular as this increase in efficiency has been, it cannot continue indefinitely. If the Nation's population doubles in the next half-century and if the level of living continues to climb, the demand for food and fibre can be expected to more than double.

NEW LAND AND POTENTIAL WATER RESOURCES

Before long, agricultural surpluses should be non-existent with the Nation's population increasing by almost 8,000 a day and the good crop land being diverted to non-agricultural purposes at the rate of about 5,000 acres a day[10B] As old land goes out of production, new land must be sought. The majority of this land is in the West; consequently, it will require irrigation. It should be remembered that initiation of projects to produce new crop land does not immediately transform land into usable, productive acreage. The size, complexity and cost of some of the required projects and the amount of construction and development necessary will delay the day of full production some 15 to 25 years after a program has been initiated.

The Bureau of Reclamation has identified 1,085 potential projects in the West from which water resources may be derived. These would provide almost 20 million acres of newly irrigated land requiring a total of about 70 million acre-feet of water per year.[10B] The cost would be about $29 billion with $12.7 billion of this allocated to irrigation. These projects would require construction of vast multiple-purpose facilities (hydroelectric power, municipal supplies, recreation), so the cost would be divided among the users.

Such an ambitious program will undoubtedly encounter very serious obstacles since it calls for interbasin transfers of water which mean more controversy and litigation over water rights. Because some of the projects are far too expensive to be considered in the foreseeable future, it is probable that only about 80 percent of the program could be completed by 2000. The cost of the remaining

TABLE IV. ESTIMATED CHANGES IN IRRIGATED ACREAGE AND WATER REQUIREMENTS FOR YEARS 1957, 1980 AND 2000*

Region	Acres (Million)			Water Required (Thousand Acre-Feet)		
	1957	1980	2000	1957	1980	2000
Eastern	2.4	3.7	16.4	5.6	7.4	26.6
Western	32.0	33.0	41.4	127.7	106.2	110.6
United States	34.4	36.7	57.8	133.3	113.6	137.2

*For 1980 and 2000, water requirements are based on assumed increased efficiency in use. Based on data from Committee Print No. 13, Select Committee on National Water Resources, U. S. Senate 1960.

projects could be so high that vast federal appropriations would be required. Support might wax and wane with the budgetary mood of future administrations and congresses. The cost of land improvement programs in the East would also be a factor.

To repeat for emphasis, a major future decision facing the West is *utilization of its land.* Since this implies economic, political and sociological changes which run counter to the interests of various groups and individuals, any major changes will not come easily. If the West converts from irrigation agriculture which uses and depletes staggering amounts of water, to industry which depletes only a small portion of the water it uses, that region could maintain healthy economic and population growth for some time to come. The West can hardly support irrigation agriculture and continued rapid population growth. The problem is first one of decision and policy formation. Implementation should not be difficult if the future economic development of the region is a primary goal.

STORAGE DAMS AND RESERVOIRS

The primary method for developing water sources for irrigation is construction of storage facilities. The West and to a considerable extent the East experience great seasonal fluctuations in stream flow. In order to insure adequate irrigation (and other) supplies, stream flow must be uniform and controllable over the year, and this is a primary function of great reservoir systems. However, these are not without their attendant problems. Conflicts of interest arising over inundation of valuable land are particularly pressing in the populous East where flood plains suited for water storage are being rapidly enveloped by urbanization and industrialization. Skyrocketing land values have made most desirable reservoir areas prohibitively costly.

Aesthetic considerations are becoming increasingly important in this era of more leisure time for all. The burgeoning population not only requires more water, it also requires more recreational areas where water sports can be indulged in. This means that those who desire to maintain the scenic beauty of potential water-storage sites will meet stiff opposition. Such an issue was fought recently over a proposed dam at Echo Park in Dinosaur National Monument which would have flooded the magnificent canyons of the Yampa and Green Rivers. Plans for construction of this dam have been abandoned for the present. Another controversy now rages over how best to deal with flooding of the Rainbow Bridge National Monument when the Glen Canyon Dam is built on the Colorado River.

This continuing and widespread development of water supplies in the West means that by 1980 maximum use will have been achieved in most areas. No additional development will be possible throughout the entire Southwest, the Great Basin states or in the upper Missouri River Basin. By 2000, Texas, Oklahoma, Kansas and Colorado

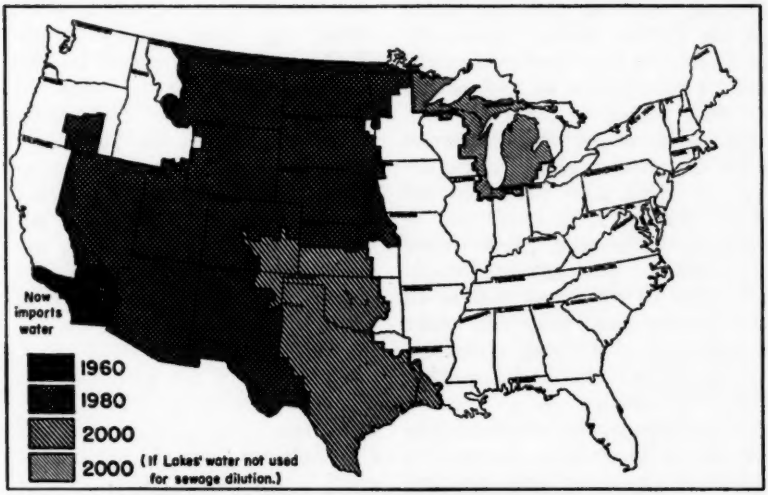


FIGURE 5: A TIMETABLE OF WATER RESOURCE DEVELOPMENT

The eastern half of the United States, and the West Coast north of Southern California have adequate water resources extending beyond the next forty years. The mid-continent area is expected to have developed all its resources by the year 2000.

also will have fully developed their supplies. Moreover, unless the Great Lakes are more extensively developed as a source, Michigan, eastern Wisconsin and the Chicago area will be using their total water supplies.[10] It is to be expected that any development plans to relieve these areas would run into opposition from other states bordering on the Great Lakes and from Canada. It appears that by the end of the century, rising demand and dwindling water supplies might seriously limit further population and economic growth in all of these regions. Even now in many parts of the West, water shortage makes it difficult, if not impossible, for communities and even entire regions to attract industry.

INDUSTRIAL DEMANDS

Industrial use of water is growing very rapidly. Among manufacturers the heaviest users are the iron and steel, chemical, pulp and paper, food, aluminum and copper industries. The mineral industries, principally petroleum refining, are also heavy users.

Opinion is divided on how much water industry will consume in the future. Resources for the Future, Inc., has surveyed future demands of the principal water-using manufacturing industries. These will almost triple by 1980 and increase almost sixfold by 2000. (9,807.3 billion gallons in 1959; 26,535.8 billion gallons in 1980; and 61,585.3 billion in 2000). Projections made by the Business and

Defense Services Administration of the United States Department of Commerce show increases to 21,662.1 billion gallons by 1980 and to 40,204.5 billion in 2000.[10c] Both agencies agree on what industries show the greatest gains. Since the way in which these industries use water differs, it is important to consider differential gains shown in Table V. The greatest forseeable gain in water use will be in the chemicals and pulp and paper industries. Percentage declines are predicted for all of the other industries listed.

These changes in industrial water use will seriously change the quality of the water since chemical and pulp and paper manufacturing processes heavily pollute surface waters with undesirable, toxic and persistent chemicals.

The demand for water among the manufacturing industries will vary in quantity across the country. Projections indicate that it will continue to rise sharply throughout most of the East,[10c] with the largest increases expected in the Great Lakes region, along the Ohio River and in the Southeast. Demands are expected to increase only very slightly in the West, and this may reflect the anticipated slow-down in industrial development due to diminishing water supplies. In the Texas and Oklahoma region, a very sharp increase in the demand is predicted for the chemical industry; and not quite so great an increase is expected for the pulp and paper industry. The demand for industrial water will not increase much along the entire Mississippi River.

Water use by the petroleum industry will follow a different pattern. Substantial gains in demand are predicted along the upper Missouri, the Colorado River and in the Pacific Northwest. The bulk of the water demand will be in the Texas-Oklahoma-southern Kansas region and along the Ohio.[10c] In the East, the demand for water by refineries will generally increase.

Recirculation of water may prove to be an important partial solution to the industrial water-supply problem, especially in the water-short West. Most industries use cooling water only once, but if proper re-cooling facilities were de-

TABLE V. PERCENTAGE DISTRIBUTION OF WATER INTAKE REQUIREMENTS AMONG THE PRINCIPAL WATER-USING MANUFACTURING INDUSTRIES FOR THE YEARS 1959, 1980, and 2000

Industry	1959	1980		2000	
		RFF*	BDSA*	RFF	BDSA
Chemical	32.7	40.7	37.1	48.2	48.0
Steel	35.7	26.8	31.6	20.8	20.0
Pulp and Paper	21.8	26.0	24.2	26.3	26.0
Food	6.4	3.8	3.9	2.4	2.5
Aluminum	2.9	2.3	2.8	1.9	2.8
Copper	.5	.4	.4	.4	.3

*RFF, Resources for the Future, Inc.; BDSA, Business and Defense Services Administration, U. S. Dept. of Commerce. (Based on tables in Reference 10C.)

veloped this water could be re-used. To illustrate, most petroleum plants recirculate water four times, on the average,[10D] and this practice uses only two barrels of new water out of every 41 barrels.

MUNICIPAL WATER AND PER CAPITA CONSUMPTION

As might be expected, the demands for municipal use of water roughly parallel those of industrial use. Since urban development and industrial expansion go hand in hand, municipal supplies in the next several decades must be greatly increased along the Atlantic Coast and the Great Lakes, down the Ohio Valley, in the upper Mississippi Valley, in Texas, California and the Pacific Northwest.[10I] In the latter two regions, expensive, long-distance diversion will be required to increase municipal supplies. Across the East, the municipal supplies appear to be adequate, but water quality will become an increasingly serious problem in the decades ahead.

Increased urbanization and a rising level of living could reflect in the per capita consumption of water increasing from the present 147 gallons per day to 185 gallons in 1980 and to 225 gallons in 2000. By then, water metering will be universal, the cost of water will be moderately higher, and plumbing inspection and leak-detection programs will be extensive.

Per capita consumption of water differs greatly in different regions—even in cities and towns. In six states having an annual rainfall of under 15 inches, median per capita consumption was 210 gallons daily in 1954. In 11 states with rainfall over 45 inches, only 119 gallons per capita were consumed. Urban areas have higher per capita consumption than smaller communities. Where air-conditioning and lawn watering are widespread, water consumption is high. Little Rock, Arkansas, used 91 gallons per person each day while Grand Junction, Colorado, used 250 gallons.[10I]

Further increases in the demand for municipal water are dictated by several developments. Domestic consumption, now about 60 gallons per person daily, could reach 85 gallons during the next few decades, as automatic washers, garbage grinders and other water-using appliances gain wider use. As private industrial supplies diminish or become polluted, industry tends to abandon them and purchase water from municipal supplies.

The chief problems for municipal water supplies in the future undoubtedly will be lack of coordination among agencies charged with providing and improving supplies, and serious deterioration in the quality of water. Lack of coordination could result in gross inefficiencies in the distribution and treatment of water. It could also thwart adequate financing for the construction of facilities large enough to store and transport water in sufficient quantities for all. Coordination problems are now most serious in large metropolitan areas where suburbanization has produced a multiplicity of small,

independent governmental units. Currently, Chicago, Denver, Nashville, many other metropolitan areas and small communities near Portland, Oregon, are beset with entanglements of this kind.

POLLUTION A THREAT TO HEALTH

Water pollution may well be one of the Nation's most serious problems and certainly one which will be most difficult to solve. In one form or another, pollution exists in all major regions of the United States. It may be natural or man-made in origin. It is increasing at a very alarming rate and no adequate measures to correct it are in sight.

Pollutants are materials which, when added to a water supply, alter its character in such a way as to interfere with its subsequent use for any normal purpose. They include sewage and other oxygen-using wastes, chemical substances, (including detergents, insecticides and pesticides), infectious agents, plant nutrients, sediments, radioactive materials and heat. These insidious by-products of technology are so numerous that no one knows how many there are. That they endanger health as they accumulate can hardly be questioned.

Domestic sewage is broken down by the process of oxidation which withdraws the oxygen from streams and lakes into which the sewage is poured. This "biochemical oxygen demand" continues until either the sewage is completely broken down or the oxygen supply is exhausted. When the oxygen is exhausted, anaerobic decomposition begins to produce methane gas. Then a horrible, gray, stinking, slimy river results.

Long before this point is reached, however, the fish begin to disappear. Below four parts per million of dissolved oxygen in the water, desirable fish cannot survive. Rough fish, like carp, can live in lower concentrations but ultimately they, too, disappear.

The United States Public Health Service's Division of Water Supply and Pollution Control has initiated a "fish-kill project" to keep track of the effect of water pollution on the fish in rivers, streams and lakes. During the project's first seven months (June-December 1960), 6.3 million fish were reported killed in 36 states.

Industrial wastes, fish-enemy number one, killed 5.5 million. Of these, five million were killed by one spill of methyl alcohol which polluted 19 miles of the Kanawha River. Domestic sewage killed 287,000 fish; mining operations killed 250,000; agricultural poison, 73,000; unknown sources, 190,000; and "other" sources, 38,000.

A few months ago, the public health aspect of pollution was dramatized when the states of New York and New Jersey closed the Raritan Bay area to clam harvesting after it appeared that there had been association between an outbreak of hepatitis, the disease which affects the liver, and the eating of raw clams which were harvested from the polluted areas of Raritan Bay. As a result, the Public Health Service has called a con

ference (August 22-23) in an effort to clean up that area.

POLLUTION WILL INCREASE ALARMINGLY

Growth in population, urbanization and industrialization means tremendous increases in sewage and other putrescible substances. The volume of industrial and other wastes not handled by conventional sewage-treatment facilities will also increase. The geographic pattern of increased sewage loads on surface waters corresponds to patterns of increased water consumption and industrialization.

About 44 percent of all sewage and other oxygen-demanding materials now are reduced by sewage treatment plants across the country[10E] Projections suggest that 70 percent of these materials will be processed by 1980 and 80 percent by 2000. However, these data are misleading because they hide the real situation. In 1954, the Nation's water was being subjected to an oxygen-demanding load equivalent to the discharge into the water of the raw sewage of about 150 million people.[10E] Even with the increased treatment projected to 1980, this load is expected to increase to 178 million; and to drop to only 168 million by 2000.

By 1980, it is estimated that $818 million will be spent each year to control water pollution,[10E] and that despite this expenditure the Nation's streams will carry a pollution load two and one-half times heavier than can be allowed if water is to serve other purposes. Even if 88 to 90 percent sewage treatment can be achieved, the level of stream purification probably will not be adequate.

Infectious organisms in quantity pass into streams in spite of treatment, and this is a potential source of disease among water users and bathers. Plant nutrients (mainly excess nitrogen and phosphorus) cause excessive aquatic plant growth. When these plants die and decay they produce disagreeable odors and tastes. Some by-products of decay in certain algae appear to be toxic.[10E] Oil, petroleum by-products, deadly insecticides and pesticides and a host of other exotic and highly stable compounds find their way into water in great quantity and some of these are not removed by conventional sewage treatment. Herbicides and insecticides present a particularly vexing problem. Their use is so widespread that their entry into water supplies cannot be pinpointed.

Sediments carried by streams are another serious pollutant, especially when dams are built. In the West, all dams must provide a certain amount of storage space for accumulation of sediment dropped by streams as their waters become quiescent. Many water-storage projects are now seriously limited by the high rate of this sediment accumulation.

INDUSTRIAL POLLUTION SERIOUS HAZARD

No reliable analysis of water pollution by industry exists, but estimates indicate that it is much greater than the pollution from

sewage. There is a growing demand that industry provide its own waste-disposal systems, but there is little prospect that these will be adequate.

It is estimated that the pulp and paper industry alone contributes almost one third of oxygen-demanding waste.[6] This industry combined with the brewing and distilling industries, packing and slaughterhouses, food canners and freezers, textile and dying plants, petroleum refiners, and beet-sugar manufacturers, synthetic rubber producers, tanneries and soap and fat processers produce wastes equivalent to the sewage from 134 million people.[6] These are only the oxygen-demanding wastes.

Acids from mine wastes pour into rivers in the Ohio River Basin and in the upper reaches of the Potomac, Delaware, Susquehanna and Mississippi Rivers. Estimates of acid damage alone run as high as $5 million per year.[10E] Salts pour in from a variety of sources to make streams and rivers unfit for many uses. Across much of the West, and especially in the Southwest, salts leached out of the soil are washed into streams by rain or by the return flow of irrigation water. In oil-producing areas, notably in Texas and Oklahoma, brine discharge from oil wells enters streams and rivers.

In addition, acids, alkalis, oils, greases, salts of copper, zinc, chromium, cyanides, phenols, mercaptans, and radioactive materials are poured into our streams either directly or through our municipal

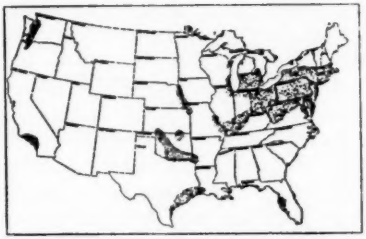


FIGURE 6: CRITICAL INDUSTRIAL WASTE-DISPOSAL AREAS

The quality of the Nation's water supply is currently endangered in the shaded areas shown on the map by the sheer volume and variety of the industrial and mining wastes which pour into rivers and streams.

systems. The existing facilities do not screen out these wastes, many of which are disagreeable in odor and taste and toxic to aquatic life. Heat destroys many organisms and causes other problems. In the Mahoning River in Ohio, repeated diversion by industry for cooling may be as much as ten times the river flow. The water temperature becomes so high in the river that, at times, normal sewage purification processes fail to operate.[7]

As might be expected from this gloomy situation, ground-water supplies are already polluted in many areas. Along the coasts—notably in southern California, southern Florida and along the Atlantic seaboard—salt water seeps in as ground water is pumped out. Detergents and insecticides are being recovered from wells; and in shallow wells bacteria pollution is especially serious. A recent survey reported that only 63 percent of the drilled wells examined were

found to be free from coliform bacteria.[10E]

The future prospect for the Nation's water supplies—one of its most crucial resources — is vital to all. The variety and quantity of pollutants now in existence and the alarming increase projected for the future give ground for the most serious concern. The sheer volume of pollutants could destroy the quality of the water in most of the Nation's major waterways. The problem which seems insoluble can be dealt with if the control and treatment methods now available are used and if a constant search is made to improve existing methods and discover new ones. Economic and political interests are involved. However, if an informed and aroused public insists, the pollution problem can be solved.

CONCLUSION

In general, the Nation's water supply appears adequate until the year 2000 for its rapidly increasing population. Unequal population growth will create serious problems, especially in the West where population gains have been greatest during past decades.

In many regions of the West, available supplies will be fully developed within the next few decades, and this will seriously limit economic development. Water supplies in the East are generally abundant, but inadequate development of existing supplies will cause local shortages.

The chief threat to the Nation's future water supply is pollution. Already alarming in extent, pollution will become even more widespread as population grows and as domestic and industrial wastes mount accordingly.

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